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A Review of Antimicrobial Activities of Cactus (*Opuntia ficus-indica*)

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Authors' contributions

This work was carried out in collaboration between authors equally. All authors read and approved the final manuscript.

Review Article

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ABSTRACT

Treatment with medicinal and aromatic plants and the use of their biologically active products, especially as anti-microbial, has become a very important and urgent matter due to the need for new anti-microbe drugs, as a result ofthe emergence of some strains of parasitesresistant to chemotherapy. Cactus (*Opuntia ficus-indica*) is an amazing multipurpose plant that has been used for thousands of years in almost all parts of the world for use as food, therapy,and other purposes. It belongs to Cactaceae family and is important in agricultural economies throughout arid and semi-arid regions. This paper reviews its traditional medicine to treat so many types of diseases. The paper also reviews the antimicrobial activity of cactus. Cactus is consumed by humans in different forms including raw, jam, juice, and in other formulated safe food products whose ingredients include cactus. This comprehensive review clearly shows that cactus is indeed a very valuable plant of the past and the future.

Keywords: Cactus; Opuntia ficus-indica; phytotherapy; traditional medicine; antibacterial; antifungal activity.

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1. INTRODUCTION

There is an increasing interest in *Opuntia ficus-indica* cultivation observed in recent years because of the importance and success of "*Opuntia*" cultivation in arid and semi-arid regions as well as for using in food and drug applications as a source of multiple products, in addition to being used as food in some areas [1,2]. Prickly pear cactus (*Opuntia ficus-indica*) belongs to shrub - like or upright type and tree-like perennial succulent with a definite woody trunk, with a large top. Reproduction is both sexual using seed and vegetative using whole cladodes and grafting is another method used to propagate prickly pears and also micropropagation [3,4].

Opuntia ficus-indica is a relatively fast growing species and fruits can be gather after three years of cultivation. Fruits have ovate or elongated shape and there are sometimes spines on them. Typical color of the fruits can be red or purplish, green, yellow or orange. The fruits are pulpy, juicy, edible, shelf stable for a few months. The pulp may be white-yellowish, orangish or purple-red. Seeds: Irregularly discoid, grey, brownish or tan [2]. It adapts to drought conditions, poor soil and high temperatures, as well as to large variations in climate and likewise, in a wide range of lands, it needs potassium and phosphorous fertilizers, and its cultivation is spread in many countries like Mexico, USA, Australia, Madagascar, Réunion, Canary Islands, Seychelles, Somalia, South Africa, Eritrea, Cape Verde, Ethiopia, Hawaii, China, India, Taiwan, Pakistan, Yemen, Costa Rica, Cuba, Honduras, Nicaragua and Puerto Rico, Bolivia, Brazil, Ecuador, Paraguay, Perue, Italy and Egypt [5].

2. REPORTS SOME OF THE PURPORTED BENEFITS

There are many medicinal uses of *Opuntia ficus-indica* according to traditional medicine in different countries, including the use of juice of spiny pear (fruits/stems) for burns treatment, irritation or infection as well as the use of prickly pear tea to assist mothers during child birth [6], abdominal pain, bronchial asthma, rheumatism, diabetes, and indigestion. Prickly pear fruit has an application in diarrhea, asthma, and gonorrhea treatment too. There are some studies were the use of fleshy stems or cladodes for high cholesterol, blood pressure, gastric acidity, ulcers, fatigue, dyspnea, glaucoma, liver conditions, and wounds treatment was studied [6,7]. There is also an evidence of use prickly pear cladodes which show anti-inflammatory activity edema, arthrosis, and whooping cough treatment and wound infection prevention [6].

Opuntia flowers can be used as a diuretic too [6]. Additional medicinal uses of cactus pear for inflammation and pain treatment [8], prevention and cure of chronic diseases, treatment of diabetes, hypertension, hypolipidemic, asthma, ulcers, rheumatic pain, wounds, and fatigue [9], as well as antiulcer-rogenic [10], antioxidant [11], and neuroprotective properties were studied [12].

Pharmacological studies reported that *Opuntia ficus-indica* are used as anti-diabetic [13], anti-hypercholesterolemic and anti-hyperlipidemic [14], anti-stress [15], antiuric, diuretic and anti-inflammatory [16], anti-cancer [17], neuroprotector [18,19], gastritis, hyperglycemia, arteriosclerosis, diabetes, and prostate hypertrophy [20]. Moreover, prickly pear is used in production of juices, jellies, candies, teas, and alcoholic drinks. The fruits and flowers are used as natural colours (natural food colorants). The flowers essential oil is used in perfumes industry. Seeds oil used as a source of animal feed [6].

It is important to clarify health benefits of *Opuntia ficus-indica* because of an increasing need of chronic diseases prevention and treatment. El-Mostafa et al. [21] observed the health benefits and curative effects of *Opuntia ficus-indica* due to its biological properties, such as anti-inflammatory, antioxidant, hypoglycemic, antimicrobial and neuroprotective properties.

3. ANTIMICROBIAL ACTIVITY OF EXTRACTS

There were gram-negative microorganisms (*Escherichia coli, Salmonella typhimurium* and *Enterobacter aerogenes*) inhibited at the concentration 2000 g/mL of mature cladode extract. Immature cladode extract was more effective and it inhibited at a concentration of 1500 g/mL. MIC values of two Gram-positive bacteria (*Staphylococcus aureus* and *Enterococcus faecalis*) were 1500 g/mL for mature cladode extract and 1000 g/mL for immature one. *Staphylococcus aureus* as a biofilm producer had MIC against planktonic cells 1000 g/ML or mature extracts and 700 g/mL for immature extracts [22].

There were some authors who reported the antimicrobial activity of *Opuntia ficus-indica*.

Ginestra et al. [23] found out that the different phytochemical fractions of *Opuntia ficus-indica* did not show antimicrobial activity against the tested bacterial strains. It has been found out the antimicrobial activity of alcoholic and aqueous extracts of *Opuntia* cladodes against *Vibrio cholerae* and *Proteus mirabilis* on the other hand [21]. There are some other studies where authors [24] described the antimicrobial activity of *Opuntia* cladodes against *Escherichia coli* and *Staphylococcus aureus* with a minimum bactericidal concentration (MBC) of 4 mg/mL and 1 mg/mL, respectively.

The antimicrobial activity of *Opuntia* cladodes extracts may be in connection with its high content of polyphenols, especially isorhamnetin which has been already reported as a substance with antimicrobial activity [25].

Bargougui et al. [26] studied methanolic crude extracts and found out that it exhibited a considerably broader antimicrobial activity in comparison with ethyl acetate extracts. The methanol extracts showed positive tests against *Staphylococcus aureus* and the inhibition zone demonstrates larger diameters than those which were obtained with other bacteria (27.00±2.47, 24.00±1.16, 29.00±2.06 and 25.00±1.66 mm) for Tunisia, Algeria, Moraco and Italy respectively. These values are the most recorded in comparison with other tested bacteria. The Moroccan cultivar has displayed the best antibacterial activity. The ethyl acetate extract also exhibits positive tests against *Staphylococcus aureus*, and the diameter of the inhibition zone was (14.00±1.77, 12.00±0.98, 11.00±1.37 and 13.00±1.47 mm) for Tunisia, Algeria, Moraco and Italy respectively. The four methanolic extracts have shown moderately positive tests for both strains (*Pseudomonas aeruginosa* and *Bacillus subtilis*) while the inhibition diameter of neomycin against these two strains proves to be 25 mm and 21 mm, respectively. It can be noted that the ethyl acetate extract does not have any action against *Pseudomonas aeruginosa* and shows a positive action against *Bacillus subtilis*.

Different cultivars of *Opuntia ficus-indica* are more active than the flowers of hexane extract against *Pseudomonas aeruginosa, Escherichia coli* and *Staphylococcus aureus*) [27]. Bussmann et al. [28] focused on antimicrobial activity of cactus extracts in their study and they found out that *Escherichia coli* was resistant to all methaolic- extract samples of *Opuntia ficus-indica* collected in the North of Peru.

In the present work, the *Opuntia ficus-indica* extract [27] as well as flowers' extract of the same species is active especially against *Aspergillus niger* and *Candida albicans*. It was confirmed that the bioactive compounds are more or less more responsible for these biological properties than the phenolic compounds. Many authors justified that these compounds have an antibacterial effect [29-31].

Welegerima et al. [32] found out that cladodes extracts of *Opuntia ficus-indica* had great antibacterial activity against both gram positive and gram negative bacteria. It seems according to this study that cladodes extracts of *Opuntia ficus-indica* have great potential and wide spectrum of inhibitory activity against both gram positive and gram negative bacteria [33]. The inhibitory activity of the extracts of *Opuntia ficus-indica* against gram positive bacteria was bigger than the inhibitory activity against gram negative bacteria on the other side. This fact is in agreement with antibacterial activity of *Opuntia ficus-indica* reported in other studies [21,33,34].

There was an antibacterial activity of hexane extract of *Opuntia ficus-indica* (OFHE) at full- and post-flowering stage against Gram-positive (*S. aureus* and *B. subtilis*) and Gram-negative (*P. aeruginosa* and *E. coli*) bacteria evaluated. The antifungal activity against *Aspergillus niger* and *Candida lipolytica* was evaluated. The antibacterial and antifungal activities were assessed by evaluating the inhibition zone. The antimicrobial activities of OFHE in the full- and post-flowering stages were in comparison with neomycin that was used as standard antibiotics positive controls and DMSO as negative controls. There is a variability in microbial sensitivity of prepared extracts. Results of this study allowed us to make conclusion that OFHE presented a marked antibacterial activity to *P. aeruginosa* for the two studied stages and *E. coli* for the post-flowering stage (D). The inhibitions remained lower than that of the positive control (neomycin 30lg/25 mm record) in all cases. We noticed that *S. aureus* was sensitive for the full-flowering (C) and post-flowering stages (D). Tested extracts showed no activity against B. subtilis in contrast to the positive control (neomycin with 21 mm of inhibition zone). There was only full-flowering stage (C) extract with low antifungal activity (10.2 mm of inhibition) to *A. niger*, while there was no marked activity for *C. lipolytica*. The antibacterial

activity for OFHE was more important than the antifungal activity for studied strains [35].

The antibacterial activity of the tested samples was noticeable more effective against the growth of Gram-negative bacteria in comparison with the Gram-positive bacteria. Gram-negative bacteria are typically more resistant to antimicrobial agents than Gram-positive bacteria. This fact could be explained by the presence of an outer-membrane permeability barrier, which limits access of the antimicrobial agents to their targets in the bacterial cell [36].

Opuntia ficus-indica (L.) Mill. fruits were used for antimicrobial evaluation using a broth microdilution assay against human pathogenic *Staphylococcus aureus* ATCC 6538, *Enterococcus faecalis* ATCC 29212, *Escherichia coli* NRLL B-3008, and *Pseudomonas aeruginosa* ATCC 10145. The minimum non-reproductive concentrations were determined as MIC, where *S. aureus* showed the most potent inhibition by 500 µg/mL [37].

Campylobacter is one of the most common causative agents of food-borne bacterial gastroenteritis in human bodies. Epidemiological studies revealed that consumption of poultry products represents important risk factor of this disease. The extracts of *Opuntia ficus-indica* have marked bactericidal effects on the growth of *Campylobacter jejuni* and *Campylobacter coli*. Moreover, adherence of *Campylobacter* to Vero cells is strongly reduced [38].

El Feghali et al. [39] made a conclusion from their results which showed that the aqueous extract of *O. ficus-indica* cladodes has inhibitory effect on *Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae* and *Pseudomonas aeruginosa*. They found out that extracts of *O. ficus-indica* were shown to exhibit antibacterial effects on the growth of *Campylobacter jejuni* and *Campylobacter coli*. De Leo et al. [40] tested methanolic, ethanolic and aqueous extracts of O. ficus-indica for antibacterial activity against *Vibrio cholera* and the most efficient was methanolic extract. There was an antimicrobial activity recorded versus *Staphylococcus aureus, Pseudomonas aeruginosa* and *Escherichia coli*. There was record also a strong antifungal effect against *Aspergillus niger*. Furthermore, *Opuntia ficus-indica* was found to exhibit a significant bactericidal effect against *Enterococcus faecium* and it was slightly able to inhibit the growth of *Candida albicans* [38]. In another studies, Sánchez et al. [41] found out that some of *Opuntia ficus-indica* cultivars could be used for their antioxidant compounds or antimicrobials against *Campylobacter jejuni, Vibrio cholera*, and *Clostridium perfringens* for control or prevention to the contamination of food.

Sánchez et al. [41] found out antibacterial activity of *Opuntia ficus-indica* cladode extract against *E. coli* (Gram-negative) and *S. aureus* (Gram-positive). There was also indicated that *O. ficus-indica* extract contains triterpenes, coumarins, quinones, tannins, carbohydrates, and flavonoids; flavonoids which cause bacterial death by inhibiting DNA or RNA synthesis and tannins including possible inhibition of extracellular microbial enzymes [42,43]. Similarly, Palmeri et al. [44] showed in their study that the *Opuntia ficus-indica* fruit extract has wide antimicrobial activity as both Gram positive and Gram negative targeted strains, supporting the potential prospect for utilization of the extract to improve overall quality and to prolong domestic shelf life of sliced beef. Hexane extracts of *Opuntia* flowers also showed high efficiency against *Escherichia coli* and *Staphylococcus aureus*, which makes this botanical source a potential contender as a food preservative or food control additive. The main compounds in the hexane extracts were 9.12-octadecadienoic acid (29-44%) and hexadecanoic acid (8.6-32%). The mucilage extract and methanol extract of *Opuntia ficus-indica* flowers both showed significant efficiency as antimicrobial and antioxidant too [26].

4. ANTIMICROBIAL ACTIVITY OF OIL

There were six different bacteria and two microscopic fungi species used to examine the antimicrobial potential of the oils extracted from the two varieties of cactus pear seeds. Oil extracted with ethanol showed the highest antioxidant activity so this oil was used for evaluation of the antibacterial and antifungal activity. The most sensitive microorganisms were *Salmonella Typhi* and *Escherichia coli* O157: H7. The first of these two microorganisms showed an inhibition zone in the presence of antibiotic agents streptomycin (S), ampicillin (AMP), and sulfamethoxazole/trimethoprim (STX) in diameters of 14.6, 11.3 and 27.3 mm, respectively while *Escherichia coli* O157:H7 was inhibited only by SXT (25.3 mm), which is in line with other studies focused on multiantibiotic resistance of *E. coli* O157:H7 [45].

Saccharomyces cerevisiae on the other hand, was highly inhibited (38–40 mm) by the extracted oils but the growth was observed only with the presence of the antimicrobial agents. There were similar results observed for *Candida albicans*, although inhibition zones were smaller and similar for both oils. These results of studies can show that certain compounds in the cactus pear seed oil have antimicrobial activity [46]. There were also other researchers who reported similar observations for cactus pear fruit cv. *Opuntia stricta* [47]. The differences in levels of antimicrobial activity can be related to variable chemical composition of the oils [48]. Mnayer et al. [49] suggested that oil compounds can act on different bacterial structures, while Gill et al. [50] mentioned that whole oils have greater antibacterial activity than the major component mixed, so that minor components are critical for the activity and exert a synergistic effect [51,52].

The *Opuntia ficus-indica* extracted oil showed an interesting antimicrobial effect on *Enterobacter cloacae*, antiyeast effect against *Candida parapsilosis*and *Candida sake*, and antifungal activity against three opportunistic cutaneous molds (*Penicillium, Aspergillus*, and *Fusarium*). Moreover, it seems that *Opuntia ficus-indica* oil has a good wound healing effect. It prevents cutaneous infections and reduces the reepithelialization phase [53].

There were compared two *Opuntia ficus-indica* seed oil fractions (glyceridic and unsaponifiable) and their biological activities. Then they were assessed with their bioactive compounds. The results of this comparison showed that antibacterial activities are variable and it depends on the fraction. In fact, unsaponifiable fraction has higher biological activities than the glyceridic ones. Furthermore, the unsaponifiable fraction was more efficient against all pathogenic strains specially *Escherichia coli* than the glyceride fraction [54].

5. CONCLUSIONS

Plant extracts are a rich source of natural compounds with antimicrobial properties, which are able to prevent, at some extent, the growth of foodborne pathogens. We can agree with several other studies showing that the inhibitory effect of phenoliccompounds from natural extracts are more effective to Gram-positive than Gram-negative bacteria similar as *Opuntia ficus-indica*. The susceptibility of bacteria to drugs depends on the characteristics of the drug and on the microbial membrane composition. The antimicrobial activity of plant phenolics has been extensively investigated against manydifferent microorganisms.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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